AIR POLLUTION & THE CHESAPEAKE BAY

ALLIANCE for the CHESAPEAKE BAY

White Paper

November 1997

White papers are published by the Alliance's Public Policy Program and are intended to provide objective, up-to-date information about policy issues affecting the Chesapeake Bay.

Introduction:

Out of thin air

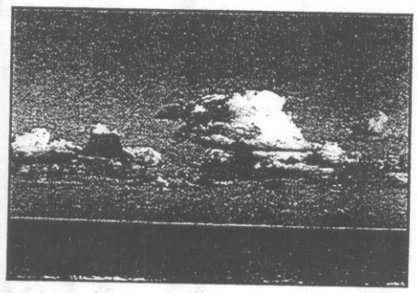
Once, efforts to clean up the Chesapeake focused almost exclusively on the Bay itself, with pollution-control efforts aimed primarily at industries and treatment plants along the Chesapeake and tidal portions of its major rivers.

Over time, it was realized that restoring the Bay also meant restoring the rivers that feed it. Cleanup efforts expanded to cover activities throughout a 64,000-square-mile watershed, which includes portions of six states.

As it turns out, even that may have been thinking too small. Some sources of pollution, particularly nitrogen, proved more pervasive and difficult to control than anticipated — it was almost as if it were materializing out of thin air. And, in fact, some of it was. It is estimated that about a quarter of all the nitrogen that contributes to the Chesapeake Bay's water quality problems is "deposited" from the sky, mostly as the result of air pollution. While a large chunk originates within the Bay watershed, a great amount also comes from far-off areas. Cleaning up the Bay may ultimately mean going beyond the watershed to control the air pollution from such distant places as Detroit, Toronto, Cincinnati and Knoxville.

Yet the task of controlling air pollution to protect water quality is one that is only slowly coming into focus. Many scientific and legal issues need to be addressed. While discharge pipes from a factory or wastewater treatment plant may go directly into a river, air pollutants often take a more indirect route to the Bay, mostly coming down on the land where they may be converted to other substances, or retained for decades. The nation's main tool for controlling air pollution, the Clean Air Act, is written primarily to protect human health. The extent to which it can be used to control pollution that threatens the health of the Bay and other water bodies remains an issue of debate.

This paper discusses some of the major issues involving airborne deposition affecting the Chesapeake and other coastal waters. Much of the recent concern has focused on nitrogen deposition, which is closely related to deteriorating water quality along the coast. But there are also concerns about the toxic substances that are delivered to the Bay and other coastal waters. Air pollution appears to be responsible for a sizable portion of the toxics entering the Bay, which may be transported from other areas, and in some cases, greater distances than is the case for nitrogen.

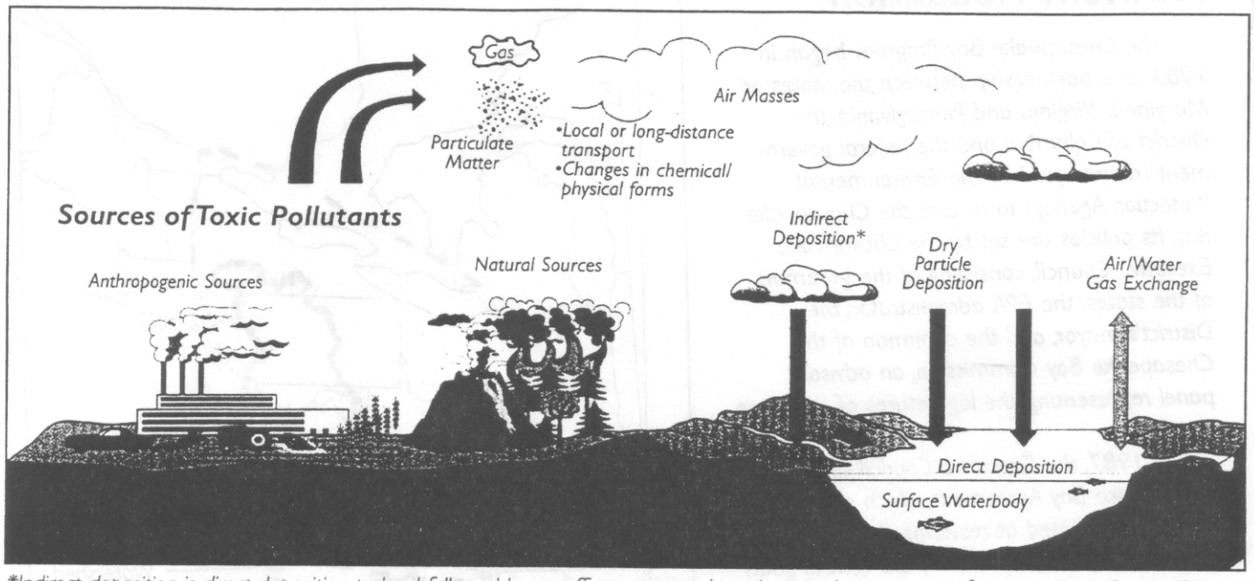


From the sky to the Bay

A little more than a decade ago, air pollution was not seen as a major problem for the Bay. That began to change in 1988 when a study by the Environmental Defense Fund estimated that about a third of the nitrogen entering the Bay was coming from the sky. Though the report was skeptically received by some at the time, a series of other studies reached similar conclusions, estimating that anywhere between 20 percent to 40 percent of the nitrogen was coming from atmospheric deposition.

In fact, recent scientific papers have suggested that the amount of nitrogen stemming from air pollution may be significant to coastal areas both in the United States and worldwic Nitrogen contributes to the loss of water quality and may be related to increased occurrences of algae blooms, such as "red tides" and

Atmospheric Deposition & How it Occurs



Indirect deposition is direct deposition to land followed by runoff or seepage through groundwater to a surface waterbody. Source: EPA

"brown tides," which are nuisances to the public and sometimes toxic to aquatic life. In all, atmospheric deposition contributes 10 percent to 70 percent of the total amount of nitrogen entering various estuaries and coastal waters.

Not only does airborne deposition contribute a significant portion of the nitrogen in the Bay and other coastal waters, it can bypass the near-shore zone where much of the nitrogen that runs off the land is absorbed by algae. Instead, the airborne nitrogen can land farther out in the water, where it adds a readily available fuel to sustain already existing algae blooms, or foster blooms in areas that once had few, if any, such events.

Types of algae that can easily assimilate this new energy source may have a competitive advantage over other types, possibly altering the base of the food web.

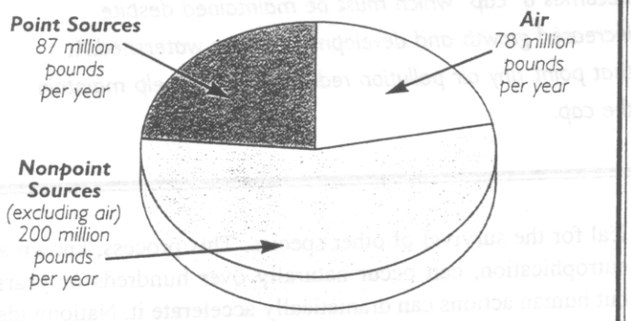
While nationwide emissions of many air pollutants have declined since the first Clean Air Act was passed in 1970, emissions of oxides of nitrogen (NOx), which stem primarily from the burning of fossil fuels, have not. Emissions of ammonia, another form of nitrogen, may also be increasing.

In the Chesapeake, nitrogen deposition is estimated to contribute about 25 percent of the nitrogen entering the Bay, or nearly 80 million pounds a year. Up to 70 percent of that is thought to stem from NOx emissions, the vast majority of which comes from human-related activities, primarily power generation and motor vehicles.

The remaining nitrogen arrives in the form of ammonia, largely from agricultural activities, where it volatilizes into the air from fertilizer and animal wastes, and from natural organic nitrogen, such as pollen.

Regardless of its form, all nitrogen that enters coastal waters is likely to be taken up by organisms in the water. Some forms will be used more quickly than others. In general, ammonia will be taken up first, followed by nitrate (stemming from NOx), then organic nitrogen compounds.

Sources of Nitrogen to the Bay



Air deposition is estimated to contribute nearly a quarter of the nitrogen entering the Bay during an average year. Nonpoint sources, which include runoff from farms, lawns, city streets and other land uses, are the largest contributor of nitrogen, followed by discharges from point sources, largely wastewater treatment plants. The figures shown here do not include nitrogen that washes in from the ocean, much of which is thought to originate from atmospheric deposition. Source: Chesapeake Bay Program

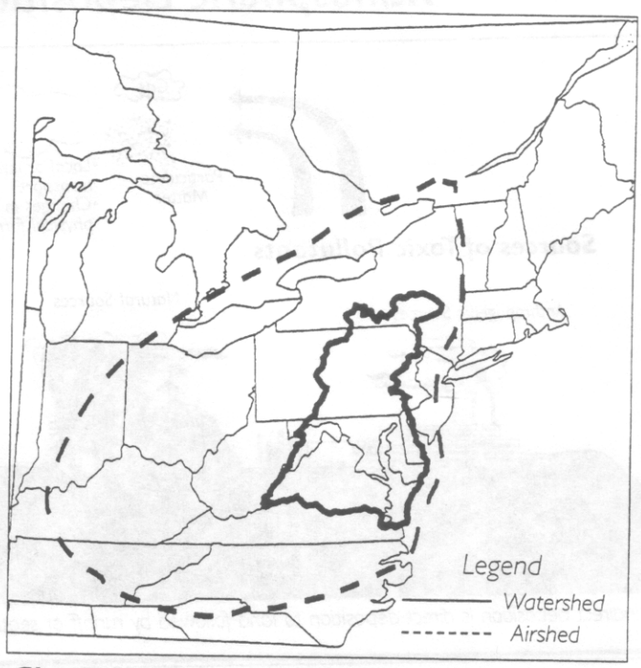
The Bay Program & Nutrient Reduction

The Chesapeake Bay Program began in 1983 as a partnership between the states of Maryland, Virginia and Pennsylvania, the District of Columbia and the federal government (represented by the Environmental Protection Agency) to restore the Chesapeake Bay. Its policies are set by the Chesapeake Executive Council, consisting of the governors of the states, the EPA administrator, the District's mayor, and the chairman of the Chesapeake Bay Commission, an advisory panel representing the legislatures of the three states.

In 1987, the Executive Council signed the Chesapeake Bay Agreement, which set a number of goals aimed at restoring the "living resources" of the Bay. One of the central goals was to reduce the amounts of two nutrients entering the Bay, nitrogen and phosphorus, 40 percent by the year 2000.

The goal has been interpreted as meaning a 40 percent reduction in the "controllable" amount of nutrients that enter the Bay. A substantial amount of nutrients were defined as "uncontrollable," including those from portions of New York, West Virginia and Delaware that are within the watershed, as well as nutrients from septic systems and those from "natural" sources (essentially those that would reach the Bay if the watershed were all forested.)

Air deposition was also considered "uncontrollable," in part because when nutrient reductions were agreed to, it was unclear how much of the Bay nutrient problem stemmed from air pollution, where it came from, and whether it would be controlled. As a result, any air pollution reductions that would be achieved by the year 2000 are not counted toward the nutrient reduction goal. But after the goal is achieved, the lowered input amount becomes a "cap" which must be maintained despite increased growth and development in the watershed. At that point, any air pollution reductions could help maintain the cap.



Chesapeake Bay Watershed & NOx Airshed

This computer model predicts where 75% of the NOx that lands on the Bay and its watershed is estimated to originate in a given year. The remaining 25% is thought to come from even farther away. Different pollutants would have different airsheds. Source: EPA

Nutrients in the Bay

Nitrogen is a fertilizer which, in the Bay, spurs the growth of algae, which form the base of the aquatic food chain. When there are more algae than can be consumed by predators, the excess may cloud the water, blocking sunlight to beds of underwater grasses which provide food for waterfowl and critical habitat for blue crabs, juvenile fish, clams and other species.

When the excess algae die, they sink to the bottom and decompose in a process that depletes the water of oxygen critical for the survival of other species. This process, known as eutrophication, can occur naturally over hundreds of years, but human actions can dramatically accelerate it. Nationwide, the National Research Council has identified eutrophication as the most serious pollution problem facing the estuarine waters of the United States.

Since 1987, the Bay states have worked to reduce t amounts of two nutrients, phosphorus and nitrogen, that enter the Bay. Phosphorus tends to promote algae in fresh water while nitrogen does so in salt water. Nitrogen is considered

Figuring the Airshed

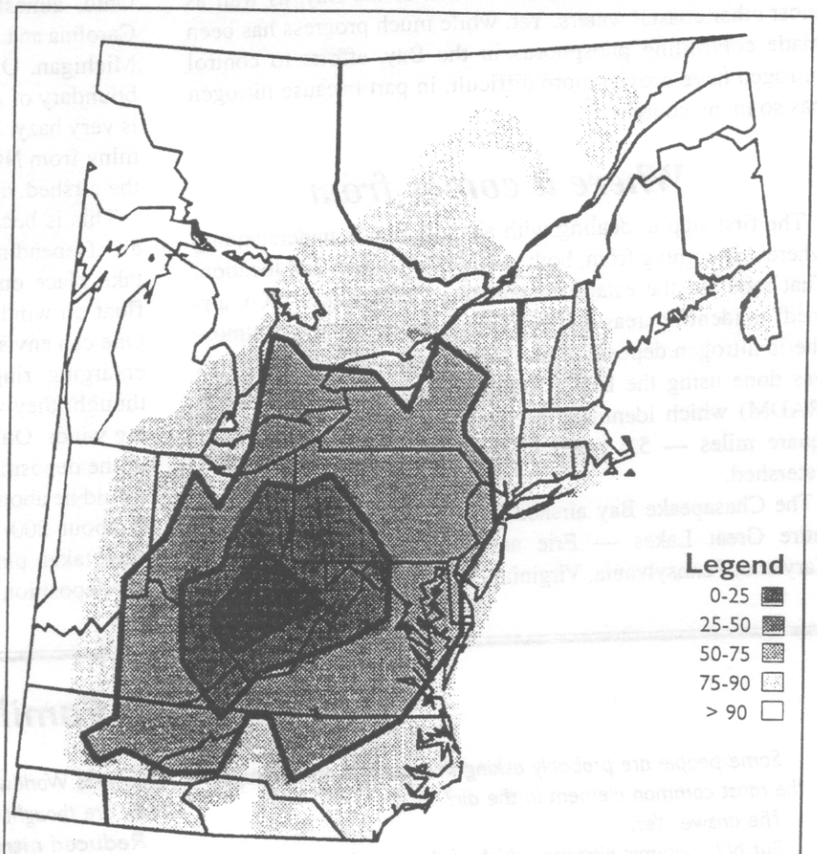
The Chesapeake Bay's "airshed" for nitrogen oxide emissions was identified using the Environmental Protection Agency's Regional Acid Deposition Model, or RADM.

The model is "three dimensional," which means it simulates the movement of air pollutants both vertically and horizontally across a region. It covers the eastern United States — from Texas and North Dakota east to Maine and Florida — with 1,368 grids, each measuring 80 kilometers square. Stacked atop each grid are 15 vertical layers. The lowest layer reaches about 75 meters into the sky, and the layers increase in thickness as they go up. The top layer touches the bottom of the stratosphere, about 15 kilometers above the surface of the Earth.

Known information about NOx emissions, using the EPA's 1990 emissions inventory, is loaded into specific grids. Those pollutants are then transported, and chemically transformed, as a weather "driver" moves them both horizontally and vertically through the model.

The weather driver uses meteorological information from many weather patterns to recreate a statistically average annual weather year. Thus, while weather patterns predominantly move from the west, the model also includes a representative percentage of "nor'easters" and other unique events to simulate the range of weather that would affect pollution transport.

To determine where deposition on the Bay and its watershed are coming from, the model was run time and again, each time tracking emissions from different "subregions." Each of these model runs took more than 60 hours on a Cray C90 computer, one of the fastest supercomputers that exists.



Nitrogen Transport Calculated by RADM

This illustrates the range of transport from a RADM "subregion" on the Ohio-West Virginia border. Contour lines indicate the percent of nitrogen that has fallen out up to that point. Source: EPA

The model was run for selected subregions (which consist of several grids) surrounding the Bay watershed and for test airsheds until sources for about 75 percent of the deposition to the Chesapeake and its watershed were identified. That took about 2,000 hours of computer time.

That left sources for 25 percent of the deposition unaccounted for. But those sources were so far away — and their emissions so dispersed before reaching the Bay watershed — that it was not considered worthwhile to go farther out.

Beyond the airshed boundary, any given subregion contributes very little individually to deposition in the watershed, but there are so many subregions contributing small amounts that — altogether — they still contribute about 25 percent of the nitrogen deposition reaching the Bay.

the nutrient of most concern in much of the Bay, as well as most other coastal waters. Yet, while much progress has been made controlling phosphorus in the Bay, efforts to control nitrogen have proven more difficult, in part because nitrogen has so many sources.

Where it comes from

The first step in dealing with air pollution is understanding where it is coming from, both in terms of sources and location. That required the establishment of a Chesapeake "NOx airshed" to identify areas that "significantly" contribute to atmospheric nitrogen deposition on the Bay and its watershed. This was done using the EPA's Regional Acid Deposition Model (RADM) which identified an airshed of more than 350,000 square miles — 5.5 times larger than the Chesapeake Bay watershed.

The Chesapeake Bay airshed is so vast that it includes two entire Great Lakes — Erie and Ontario. It covers all of Maryland, Pennsylvania, Virginia, Delaware, West Virginia and Ohio, almost all of New York, half of New Jersey, North Carolina and Kentucky, and parts of Tennessee, South Caroli Michigan. Ontario and Quebec. Unlike the firm geographic boundary of a watershed, though, the boundary of the airshed is very hazy. In fact, about a quarter of all the deposition stemming from NOx emissions originates beyond the boundary of the airshed, according to the model.

This is because of how those emissions travel through the air. Depending on the weather conditions, deposition may take place only a short distance from the source, or it may float on wind currents for days, traveling hundreds of miles. One can envision deposition from a source as a series of ever-enlarging rings. The rings would not be perfect circles, though; they would be skewed along the path of the prevailing winds. On average, according to RADM, about 25 percent of the deposition would take place within the first ring, which would be about 100 miles from the source; by the second ring, at about 200 miles out, roughly half the deposition would have taken place. By the 500-mile ring, about 75 percent of the deposition would have taken place. The remaining frac-

The Nitrogen Family

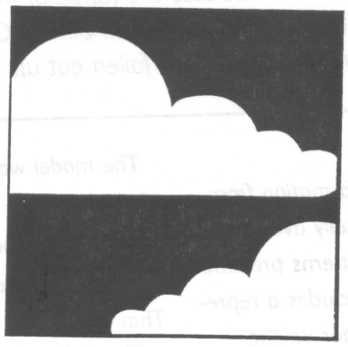
Some people are probably asking the question: Isn't nitrogen the most common element in the air?

The answer: Yes.

But N2, diatomic nitrogen, which makes up about 78 percent of the atmosphere, is inert and does not readily react with other compounds in the atmosphere.

The compounds that are generally of concern fall into three categories:

Reactive nitrogen: *This is composed primarily of nitrogen oxides. Several different oxides of nitrogen occur in the atmosphere, including nitrogen dioxide, nitric oxide, nitrous acid, nitric acid and others. Oxides of nitrogen are created when oxygen reacts with nitrogen at high temperatures when both nitrogen gas in the atmosphere and chemically bound nitrogen in material being burned can react with oxygen. This combustion typically occurs in fossil-fuel-fired electric utility plants and industrial boilers, and in internal combustion engines, such as those in cars and trucks. It is also generated from biomass burning.*

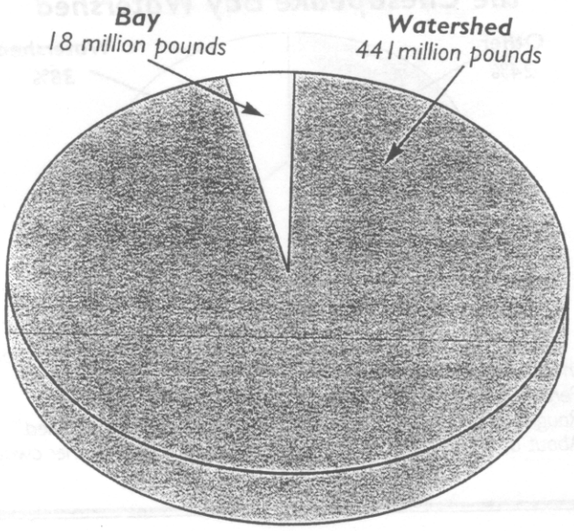


Major natural sources of NOx include lightning, which generates temperatures high enough to convert nitrogen gas into NOx, and the soil, which naturally emits nitric oxide, particularly if fertilization rates are high and soil temperatures are warm. Nationwide, the EPA has estimated that natural sources account for only about 7 percent of the total national NOx emissions. Worldwide, natural and anthropogenic sources of NOx are thought to be about equal.

Reduced nitrogen: *This is primarily ammonia, and it, too, has both natural and human sources. Natural sources stem from the decomposition of organic nitrogen compounds in soils and in the ocean, and from the volatilization of animal and human wastes into the atmosphere. Human sources include the manufacture of fertilizers and their application, which results in ammonia volatilizing into the air. Manure management techniques and biomass burning by humans may increase emissions from otherwise natural processes. Much remains unknown about how far ammonia travels through the atmosphere.*

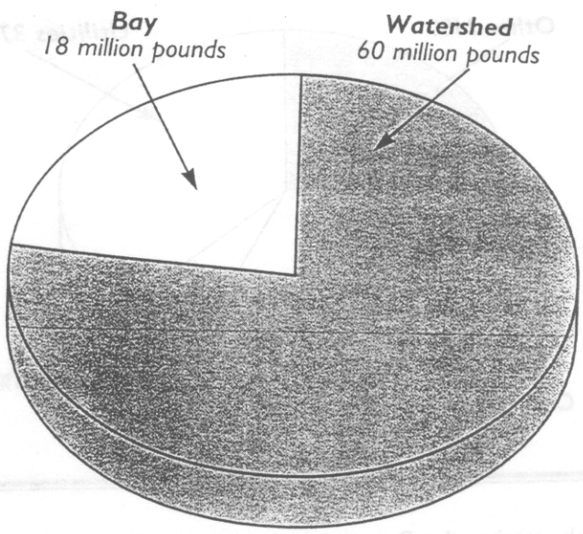
Organic nitrogen: *Of the three major forms of nitrogen in airborne deposition, the least is known about organic nitrogen, which is more difficult to monitor than the other forms. Organic nitrogen may include urea, amino acids, pollen and natural emissions in the soils. Some of it may also result from human-caused emissions which are transformed in the atmosphere. Generally, organic nitrogen is thought to be less biologically available than nitrate or ammonia, but some forms may be more readily used than others. In any case, all forms of nitrogen are likely to be used in coastal areas.*

Nitrogen Deposition & Delivery



Deposition

The greatest amount of airborne nitrogen lands on the watershed — an estimated 441 million pounds a year — compared to the estimated 18 million pounds that land directly on the Bay. Most of the deposition, up to 70 percent, stems from nitrogen oxide emissions. The rest results from ammonia emissions, largely from agriculture, and organic nitrogen.



Delivery

Most of what lands in the watershed is absorbed by plants or otherwise transformed before reaching the Bay. Only an estimated 60 million pounds — a fraction of what lands on the watershed — ultimately finds its way to the Chesapeake.

Source: Chesapeake Bay Program

tion would travel farther, perhaps hundreds of miles more.

This means, according to the model, that most of the deposition from any given source will have taken place within about 200 miles, with the rest being deposited in ever-decreasing concentrations over an an ever-expanding area as it moves away from the source. The key fact here is that there are so many distant sources that their cumulative effect on the Bay is enormous.

In fact, the majority of deposition reaching the watershed originates from areas with no physical connection to the Chesapeake. RADM shows that about 25 percent to 30 percent of the nitrogen deposited on the Bay and its surrounding watershed originates from sources within the watershed. Nearly 40 percent of the deposition originates within the Bay states of Maryland, Virginia and Pennsylvania. That means almost 60 percent of the airborne nitrogen reaching the watershed comes from beyond the Bay states.

One final note: A portion of the nitrogen reaching the Bay comes in through its mouth during tidal exchanges. As currently defined, the Bay's airshed does not include pollution sources that contribute to deposition on the coastal ocean, which may enter the Chesapeake.

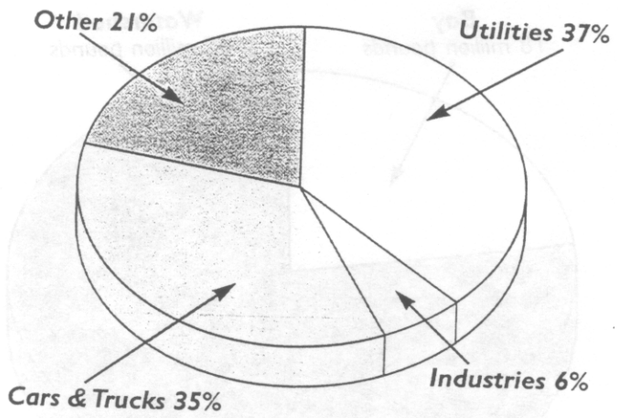
Deposition and Delivery

In the atmosphere, NOx emissions are converted to other forms of nitrogen, mainly nitrate and nitric acid, a form of acid rain. When those forms of nitrogen come down, they can enter the Chesapeake Bay directly (by falling on it or its tidal tributaries) or indirectly (by landing on the watershed and being transported to rivers and ultimately, the Bay).

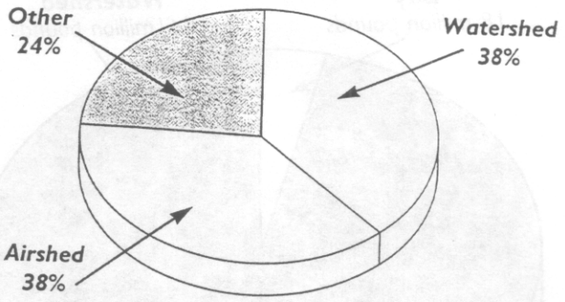
Using computer models, the Bay Program has estimated that about 25 percent of the airborne nitrogen entering the Bay lands directly on the water surface. The remainder takes a much longer path, falling onto the 64,000-square-mile watershed and gradually working its way to the Chesapeake. But all of what comes down on the watershed does not end up in the Bay. Determining the amount of nitrogen that enters the Bay from the watershed as a result of atmospheric deposition (as opposed to other nitrogen sources) is the largest single uncertainty in determining the significance of air pollution as a Bay problem.

The nation's atmospheric deposition monitoring network has collected data showing that the upper portions of the Chesapeake Bay watershed get some of the highest levels of nitrogen deposition in the country. How much of that ulti-

Types of NOx Emissions Originating in the Chesapeake Bay Region



Sources of NOx Emissions that Reach the Chesapeake Bay Watershed



About 38 percent of the nitrogen oxide emissions that land on the Bay or its watershed originate from the Bay states of Pennsylvania, Maryland, Virginia and the District of Columbia. Roughly an equal amount stems from the surrounding "airshed." About a quarter of what lands originates from even farther away.

mately reaches the Bay remains a question. Much of it is absorbed by plants or removed through chemical processes. Making these estimates is difficult because airborne nitrogen does not wash off the land at a steady rate. Instead, it tends to be flushed out during heavy storms, when much of the deposition may be washed directly across the land and into streams without being exposed to vegetation, which acts as a buffer. Storm events are difficult to monitor, adding another layer of uncertainty to estimates of deposition export from the land.

Because of the vast amount of nitrogen that is deposited on the watershed, even a small change in assumptions about the "retention" rate of nitrogen on the land could dramatically increase, or decrease, estimates of the total amount of nitrogen actually reaching the Chesapeake. Despite these uncertainties, several independent estimates over the past decade have placed the total atmospheric contribution to the Bay's nitrogen "load" in the 20 percent to 40 percent range.

Estimates of Air Deposition's Contribution to Annual Nutrient Loads in Selected Estuaries

Estuary (States)	Percent of Load from Atmospheric Deposition
Albemarle-Pamlico Sounds (NC)	44
Chesapeake Bay (MD, VA)	27
Delaware Bay (DE, PA, NJ)	15
Delaware Inland Bays (DE, PA, NJ)	21
Flanders Bay (NY)	7
Guadalupe Estuary (TX)	2-8*
Long Island Sound (NY, CT)	20
Massachusetts Bays (MA)	5-27*
Narragansett Bay (RI)	12
New York Bight (NY, NJ)	38
Sarasota Bay (FL)	26*
Tampa Bay (FL)	28*
Waquoit Bay (MA)	29

* Includes direct deposition to surface of waterbody only. Others also include deposition flowing out of watershed

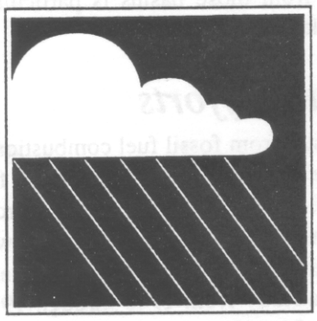
From Smokestacks & Tailpipes to the Bay

Using the airshed defined by RADM, it is possible to look at EPA emission data to determine what sources contribute to nitrogen deposition on the Bay and its watershed. RADM, using 1990 emissions data, provided the following breakdown of emissions sources within the airshed:

- ❑ Electric power plants account for 37 percent of emissions. About 85 percent of all NOx emissions from electric utilities is attributed to those burning coal.
- ❑ Industries and other plants with large, fossil-fuel-fired boilers account for 6 percent.
- ❑ Cars and trucks account for 35 percent.
- ❑ Other sources account for 21 percent. This includes emissions from ships, boats, lawn mowers, airplanes, construction equipment,

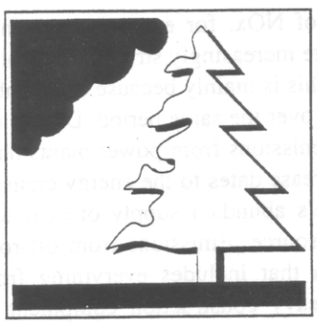
Nitrogen in the Air: Multiple Im

Many people identify nitrogen as a fertilizer that helps lawns, trees and gardens grow. It is essential to life. In years past, snow — which is particularly effective at filtering nitrogen out of the air — was sometimes referred to by farmers as "the poor man's fertilizer." Yet in excess amounts, nitrogen, like anything else, can cause problems. A recent report from the Environmental Protection Agency, "Nitrogen Oxides: Impacts On Public Health and the Environment," attempted to look at the multiple impacts of NOx to help decision makers develop control policies. Besides contributing to eutrophication and to human health problems associated with high concentrations of ground-level ozone, the report said NOx emissions can contribute to:



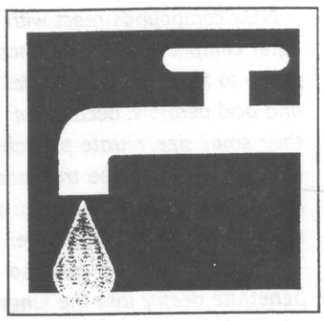
Acid Deposition

Sulfur dioxide and NOx are the two key air pollutants that cause acid rain. Acid rain can change soil chemistry which, in turn, can reduce growth in some trees, as well as their ability to resist disease. As lakes and streams become acidified, they may lose fish biodiversity, including some sensitive species such as trout. Sudden acidic "pulses" can release aluminum — which is highly toxic to fish — and other metals into streams, especially during spring spawning periods when rain and snow melt contribute large amounts of acid at once. Acid rain can damage a wide range of materials, from galvanized steel and copper to stone in buildings and monuments.



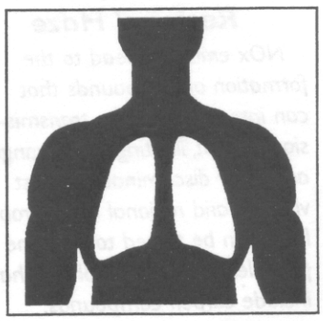
Nitrogen Accumulation in Terrestrial Ecosystems

Nitrogen can accumulate in watersheds with high atmospheric deposition. In most ecosystems, nitrogen deposition has a fertilizing effect that accelerates plant growth. Although this is often considered beneficial, it can also cause adverse changes such as a shift in plant species composition, a decrease in species diversity, and the leaching of nitrate to surface and ground waters. Studies in prairie ecosystems, for example, have shown that increased nitrogen loadings lead to the increased abundance of nonnative species, the loss of native species and the disruption of ecosystem functioning. Some trees and plants in nitrogen-saturated areas may be more susceptible to insect and disease attacks.



Drinking Water Nitrate

High levels of nitrate in drinking water constitute a health hazard, particularly for infants, in whom they can contribute to the "blue baby" syndrome. High nitrate levels in water may also increase cancer risks in adults. Atmospheric nitrogen deposition in sensitive watersheds can increase stream water nitrate concentrations. This added nitrate can remain in the water and be transported long distances downstream.



Nitrogen Dioxide

Exposure to NO_2, another breakdown form of NOx, is associated with a variety of acute and chronic health effects. The health effects of most concern include mild changes in airway responsiveness and pulmonary function in individuals with pre-existing respiratory illnesses and the increase in respiratory illnesses in children. All areas of the United States monitoring nitrogen dioxide are below the EPA's threshold for health effects.

Stratospheric Ozone Depletion

Stratospheric ozone protects people, plants and animals on the Earth's surface from ultraviolet radiation. Nitrous oxide, which is very stable in the lower atmosphere (troposphere) slowly migrates to the stratosphere where solar radiation breaks it into nitric oxide (NO) and nitrogen (N). The NO reacts with ozone to form nitrogen

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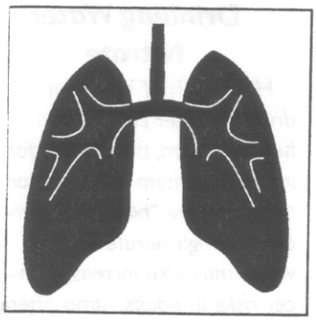
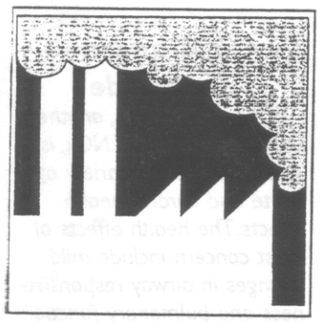
dioxide and molecular oxygen, so additional nitrous oxide emissions would result in some decrease in stratospheric ozone.



Particulate Matter

NOx compounds react with other compounds in the atmosphere to form nitrate particles and acid aerosols. Because of their small size, nitrate particles have the ability to be transported hundreds, even thousands, of miles though the atmosphere. These small particles can also penetrate deeply into the lungs where they can contribute to a wide range of adverse health problems in children and adults.



Visibility & Regional Haze

NOx emissions lead to the formation of compounds that can interfere with the transmission of light, limiting visual range and color discrimination. Most visibility and regional haze problems can be traced to airborne particles in the atmosphere that include carbon compounds, nitrate and sulfate aerosols and soil dust. The major cause of visibility impairment in the eastern United States is sulfates, while in the West the other particle types play a greater role.

Toxic Products

Airborne particles derived from NOx emissions react in the atmosphere to form various nitrogen-containing compounds, some of which may be mutagenic. Examples of transformation products thought to contribute to increased mutagenicity include the nitrate radical, peroxyacetyl nitrates, nitroarenes and nitrosamines.

trains and other sources which generally do not fall into the other categories.

When comparing emission sources to deposition, RADM shows that a significant pattern emerges. A disproportionate amount of the car and truck emissions take place in cities and heavily developed areas relatively close to the Bay. As a result, their emissions are more likely to result in direct deposition to the Bay and its tidal waters.

By contrast, utilities, which are heavily concentrated to the west of the Bay, have NOx emissions that are likely to be deposited on the upper portions of Chesapeake drainage, on the Susquehanna and Potomac watersheds. Both drainages are dominated by forests which are capable of absorbing much of the nitrogen, so there is more uncertainty about how much deposition in those areas actually reaches the Bay. On the other hand, those rivers supply about three-quarters of the Bay's fresh water and tend to have the greatest impact on its water quality, so nitrogen from those basins is particularly significant to the Chesapeake.

Control efforts

NOx emissions stem mostly from fossil fuel combustion at high temperatures. They are produced from automobiles, factories, power plants, boats, locomotives and other sources. Historically, NOx emissions have been closely linked with economic and population growth in the country. Nationally, NOx emissions grew dramatically from 1940 through 197(increasing from 7 million to 21 million tons a year.

Efforts beginning with the Clean Air Act of 1970 helped to slow the growth in NOx emissions, and on a per-capita basis they peaked in the United States in 1973. But total NOx emissions, according to EPA figures, increased by about 12 percent from 1970 through 1994, even as many other air pollutants of concern declined. The reason is that demand for fossil fuel — either for vehicles, electricity or other purposes — has continued to grow.

National auto emissions of NOx, for example, remain at about their 1970 level despite increasingly stringent air pollution control requirements. This is mainly because the number of miles driven has doubled over the same period. During the past quarter century, NOx emissions from power plants have increased. Much of that increase dates to the energy crisis of the 1970s, when the nation's abundant supply of coal was viewed as a preferred fuel source. Emissions from off-road vehicles — a classification that includes everything from planes, trains, ships and heavy construction equipment to lawn mowers, power boats, chain saws and the like — have grown from 1.6 million tons to about 3 million tons over the same time period. Historically, those sources have been largely unregulated.

In large part, NOx emissions grew because the original 1970 Clean Air Act was primarily designed to protect public health, and direct emissions of NOx were not seen as a major

health threat. While pollution control devices for new cars, factories and power plants helped to curb NOx emissions, nitrogen oxides were not targeted with the same vigor as were lead, carbon monoxide and other pollutants with a clear and direct human health link.

That began to change with the Clean Air Act Amendments of 1990. At that time, scientific evidence was mounting that efforts to control ground-level ozone — a pollutant linked to respiratory problems — had failed in many areas because NOx had not been controlled enough. Ozone is formed when the mixture of NOx and volatile organic compounds — hydrocarbons that vaporize into the air — is oxidized on on hot, sunny days. Before 1990, ozone control efforts were focused primarily on volatile organic compounds, but in recent years, emphasis has been shifting toward NOx, based on new research.

The new concern over ozone set the stage for stricter controls on NOx emissions. The 1990 law required a 60 percent reduction in NOx emissions from tailpipes, as well as a study of further auto emissions reductions. It also set up the Northeast Ozone Transport Commission, consisting of all the states from Maine to Maryland as well as the District of Columbia and its northern Virginia suburbs, which for the first time began controlling NOx emissions on a regional basis to reduce chronic East Coast summertime ozone problems. That resulted in an agreement under which major power plants in the region are to reduce NOx emissions 55 percent to 65 percent during the summer months by 1999.

Also, the 1990 amendments dealt with acid rain control for the first time. The law required a 10-million-ton reduction (roughly 50 percent of 1980 emissions) in nationwide emissions of sulfur dioxide from fossil-fuel-fired electric power plants, which were considered the main contributor to the acid rain problem. The law also directed that total sulfur dioxide emissions be capped at that lower level. At the same time, utility NOx emissions, which produce nitric acid, were slated for a 2-million-ton (roughly 25 percent of the utility emissions) reduction by 2000, though total emissions were not capped.

By the mid-1990s, as the acid rain reductions began to take effect, nationwide NOx emissions — particularly those from

New Air Standards

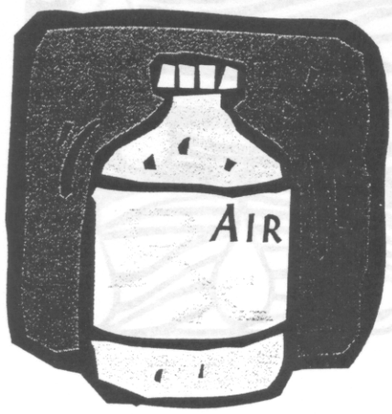
Ozone

❑ *The standards is 0.08 parts per million of ozone averaged over 8 hours. This replaced a standard of 0.12 parts per million measured over one hour.*

❑ *The new standards extend more health protections to 35 million people, bringing to 113 million the number of Americans protected by the air quality standard for ozone.*

❑ *The standards are expected to help children by reducing respiratory problems such as asthma attacks. It is expected to result in 1 million fewer incidences of decreased lung function in children each year.*

❑ *States and counties will have at least until the year 2004 to meet the new standards.*



Particulates

❑ *The standard for coarse particles remains essentially unchanged, while new standards for fine particles — less than 2.5 microns, or about 1/28th the thickness of a human hair — are set at an annual limit of 15 micrograms per cubic meter, with a 24-hour limit of 65 micrograms per cubic meter.*

❑ *This is the first time the government has set a public health standard for fine particle pollution.*

❑ *Scientists say that fine particles are some of the most damaging to human health because they penetrate and remain in the deepest passages of the lungs.*

❑ *The new standard provides new protections to nearly 70 million Americans, and will prevent approximately 15,000 premature deaths a year.*

❑ *The EPA will allow five years to build a nationwide monitoring network to gather and analyze the data needed to designate nonattainment areas and gather information needed to write plans to control particulates.*

❑ *The EPA will allow another three years for areas that are not in compliance with the standard to develop plans, and several more years to actually comply with the standard.*

— Source: EPA

power plants — began to decline, falling in both 1995 and 1996.

Recent Efforts

Despite control efforts under way or planned at of the end of 1996, the EPA estimated at that time that NOx emissions would decline only until 2002 when increased growth would begin pushing them up again. But several initiatives since 1996 could further reduce NOx emissions and deposition on the Bay and its watershed.

One major initiative stemmed from the Ozone Transport Assessment Group, an organization made up of the 37 states east of the Rocky Mountains and the EPA. Despite efforts by states in the Northeast Ozone Transport Commission, many East Coast urban areas still fail to meet the EPA's air standard for ground-level ozone. Other large urban areas, such as Chicago, also appear likely to exceed the standard far into the future. In large part, that is because much of the nitrogen oxides that contribute to ozone generation are blown in from distant sources beyond their control — just as much of the nitrogen deposition on the Chesapeake watershed stems from outside the Bay region.

After two years of work, OTAG in the summer of 1997 released recommendations that called for sharp reductions — up to 85 percent from individual sources — in NOx emissions, specifically targeting coal-fired power plants in the Midwest. Because many of those plants are located in areas that already attain the ozone standard, they were not previously subject to the sharp NOx emission reductions agreed to along the East Coast even though they contributed to downwind problems. If the OTAG recommendations are fully implemented, it is estimated that the emission reductions would bring most of the eastern urban areas closer to compliance with existing ozone standards.

Also in the summer of 1997, the EPA issued slightly more

Uncertainties

Concern about the impact of air pollution on eutrophication has spurred increased research over the past decade, but major uncertainties remain in estimating the extent of the problem.

One of the biggest problems is measuring just how much nitrogen is being deposited from the sky. While measuring what is in rainwater — so-called "wet deposition" — is fairly straightforward for most nitrogen compounds, nitrogen also falls to Earth when it is not raining, and measuring this "dry deposition" is much more difficult. The amount of dry deposition that lands in a particular area will be affected by biological factors and land surfaces. (Hills will intercept more material than flat land.) Moisture in the air, and even the wetness of leaves can affect dry deposition. In practice, it is assumed that dry deposition is generally equal to wet deposition, though no one knows whether — across a watershed so vast as the Chesapeake's — this is an overestimate or an underestimate.

Up to three-quarters of the atmospheric nitrogen that enters the Bay originally lands on its 64,000-square-mile watershed. Soil and vegetation act as a natural filter, absorbing much of the nitrogen deposition just as it would other fertilizers. Estimating how much of the atmospheric nitrogen is retained and how much is passed through is difficult; even small changes in the assumptions used, when multiplied over a huge watershed, can greatly increase or decrease estimates of the amount of atmospheric nitrogen working its way from distant forests to the Chesapeake Bay.

Other ares of uncertainty include:

- *Ammonia and organic compounds contribute 25 percent or more of the total atmospheric nitrogen load to the Bay. But they are difficult to monitor and there are many questions about their transport. They could prove important, though, as ammonia emissions from agriculture could increase in the watershed as animal operations expand.*
- *Emission estimates will continue to be refined over time. Some sources are likely undercounted, such as ship emissions in harbors. While those may be small compared with the total nitrogen load to the Chesapeake, their proximity to the water means that a large proportion would be directly deposited to the Bay.*
- *Amounts entering the Bay from atmospheric deposition on the coastal ocean, which enters the Chesapeake during tidal exchanges, remain uncertain.*

Clean Air Act Programs

The Clean Air Act does not set limits for NOx in the air nor does it limit total NOx emissions, as is the case with some other pollutants. Nonetheless, several clean air programs affect NOx emissions, primarily as a means of reducing the amount of ground-level ozone in the air, and to control acid rain.

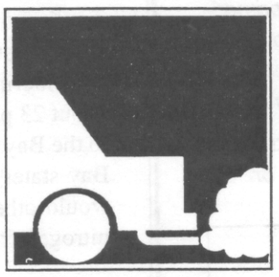
Here is an overview of Clean Air Act programs that relate to NOx emissions.

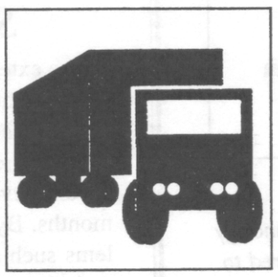
Mobile Source Programs

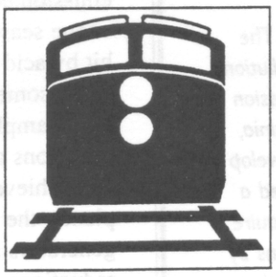
Tailpipe standards: *These date to the original 1970 Clean Air Act and have become more stringent over time as pollution control devices have become more effective. Through the early 1990s, those efforts were enough to keep auto emissions level despite a dramatic increase in miles traveled. The 1990 Clean Air Act required a further 60 percent reduction in emissions, which was phased in during the 1994 and 1996 model years, though its impacts won't be fully realized until after 2000 because of the time it takes for older vehicles to be replaced by newer ones. In addition, the EPA and automakers are working on standards for a National Low Emission Vehicle, which would reduce NOx emissions by another 50 percent. These vehicles could be on the road around the turn of the century, though the full impact of the program would not be realized until 2015. The EPA is currently studying whether more stringent tailpipe standards will be needed to improve air quality in the face of anticipated growth.*

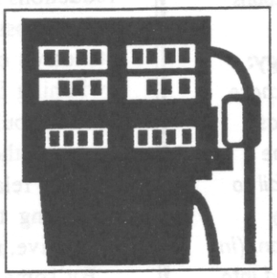
Onboard Diagnostics: *The Clean Air Act requires the incorporation of on-board diagnostic systems to determine whether emission control devices are functioning properly. This program is still in development, but it is expected that it could reduce the cost of emission compliance by quickly notifying drivers and mechanics when emission system problems emerge.*

Supplemental Federal Test Procedure: *The Clean Air Act required the EPA to re-examine its emission test procedures for cars and light-duty vehicles. This re-examination found that the tests did not adequately account for real-world driving behavior, higher speed limits and the operation of air conditioners. As a result, the EPA in 1996 determined that emissions had to be decreased about 10 percent to meet the current emission limits.*









Inspection and Maintenance: *Poor maintenance and deliberate tampering has resulted in motor vehicles consistently emitting pollutants in excess of established standards. As a result, many areas with problems attaining air quality standards have been required to initiate emissions inspection systems for vehicles. Newer inspection and maintenance systems, going into use in portions of Maryland, Pennsylvania and northern Virginia are able for the first time to monitor NOx emissions, though the programs have been controversial in some areas and generally cost more than older emission inspection programs.*

Highway Heavy Duty Vehicles: *Engines for heavy-duty trucks have had to meet increasingly stringent NOx emission standards from 1985 though 1998. The EPA has proposed new standards that would be effective beginning with engines manufactured in 2004, which would require an additional 50 percent reduction in NOx emissions.*

Nonroad engines

The EPA in 1994 issued regulations to control most NOx emissions from equipment used in agriculture, construction and general industry diesel engines. The rule set phased in standards for engines manufactured from 1996 though 2000, depending on their size. The EPA intends to propose additional standards in the future. The EPA is developing emission standards for locomotives, the second largest producer of nonroad NOx emissions. The EPA is working with international marine and aviation organizations about the possibility of control measures on airplanes and large shipping vessels. Reductions from nonroad sources tend to be particularly effective, and relatively low in cost, because their emissions have not been previously controlled.

Fuels Programs

Gasoline: *Reformulated gasoline is required in some areas that fail to meet the ozone standard to reduce emissions. The original, Phase I, program was intended primarily to control emissions of volatile organic compounds which contribute to ozone creation, but it also resulted in a*

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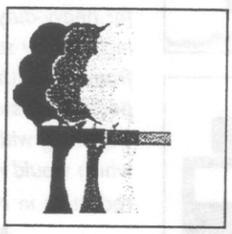
small, roughly 1.5 percent, decrease in NOx emissions. A Phase II reformulated gasoline program to be implemented in the summer of 2000 will require a 6.8 percent reduction in vehicle NOx emissions.

Stationary Source Programs

Acid rain: *Under a two-phase program, coal-fired power plants were to reduce nationwide NOx emissions by 2 million tons a year by the year 2000. Phase 1 of the program, which affected 277 boilers, went into effect in 1996. Phase 2, affecting another 775 boilers, takes effect in 2000. The reductions are made primarily by applying "low NOx burner" technology at power plants. The law does not "cap" total NOx emissions at the reduced level, so they could increase over time.*

New Source Review Program: *In areas that fail to meet the federal ozone standard, major new or modified sources are required to control emissions by the Lowest Achievable Emission Rate (this does not take cost into account), and to offset the new emissions with reductions from other sources. In areas that meet the ozone standard, new sources are required to control emissions by the Best Available Control Technology (this takes costs into account) and are not required to offset new emissions.*



Northeast Ozone Transport Commission: *The 1990 Clean Air Act, recognizing the problem of pollution transport, established the Ozone Transport Commission consisting of the District of Columbia, northern Virginia, and all states from Maryland through Maine, to develop regional ozone control strategies. These states signed a Memorandum of Understanding which generally require existing major power plants to reduce NOx emissions by 55 percent to 65 percent in addition to NOx reductions being made under the acid rain program.*

Reasonable Available Control Technology: *Certain existing major sources of NOx must purchase and install reasonable available controls to decrease NOx emissions if they are in the Northeast Ozone Transport Region or in certain other areas that fail to meet the federal ozone standard. These generally require a 30 percent to 50 percent NOx reduction. (In the Northeast, these reductions were incorporated into the Ozone Transport Commission's Memorandum of Understanding.)*

stringent standards for ozone, as well as the first-ever standards for concentrations of fine particles that are smaller than 2.5 microns, or about 4 percent of the width of a human h For some areas, meeting these standards would require additional NOx reductions beyond those recommended by the OTAG.

Exactly how the reductions recommended by OTAG and required for the new air standards are to be achieved will be worked out in coming years. Pollution reductions stemming from those efforts are not likely to be seen within the Bay watershed until the turn of the century, and may not be fully realized for another decade or more.

But one initial estimate by the EPA showed that implementing the OTAG recommendations and meeting the new clean air standards could reduce the amount of airborne nitrogen entering the Bay by nearly 17 million pounds a year — or about 23 percent of all the airborne nitrogen that finds its way to the Bay. That, according to an EPA estimate, could save the Bay states about $360 million in implementing controls that would otherwise be needed to keep an equivalent amount of nitrogen from other sources out of the Chesapeake.

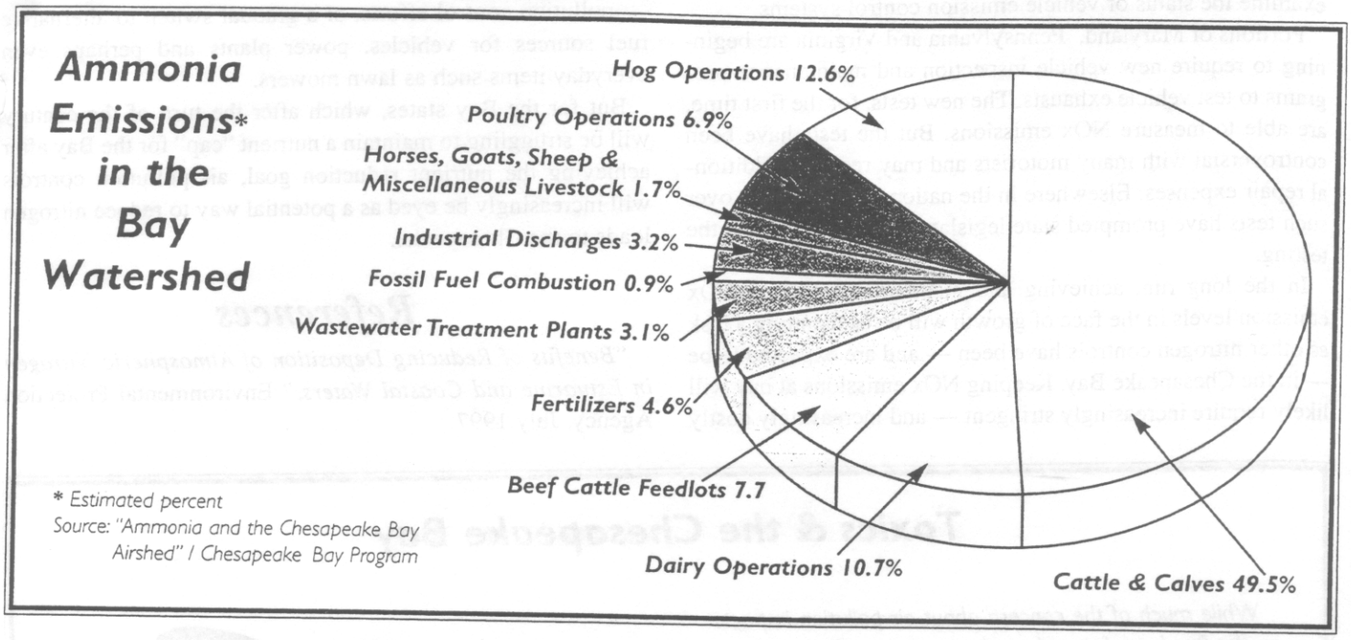
Seasonal or Year Round?

The extent to which the Bay and other coastal waters benefit from new clean air activities will depend on decisions made in the next several years. Most of the anticipated NO emission reductions are needed to meet ozone standards. b ground-level ozone is only a problem during the summer months. By contrast, nitrogen deposition contributes to problems such as coastal eutrophication and acid rain all year. If emission control programs are designed only for the summer ozone season, then the benefits for the Bay and regions hard hit by acid rain will be minimized.

For some emission sources, this does not make a difference. For example, pollution controls on motor vehicles will reduce emissions all year, though the additional use of reformulated gas achieves greater reductions in the summer. With power plants, the issue may be more complex. Many large power generators are already installing "low NOx burners" to make reductions required for acid rain regulations.

It is possible that the further reductions to achieve ozone standards could be achieved during the summer months by switching from coal to other fuels, such as natural gas. Such actions could lead to dramatic NOx emission reductions in the summer, though emissions during the rest of the year would remain relatively high. But technologies other than fuel switching to achieve year-round reductions would require expensive. new control devices at power plants.

By some estimates, these technologies could cost several thousand dollars per ton of NOx removed. Because otl recent actions are likely to result in a downward trend in NOx emissions for the next decade or more, some argue that these controls are not worth the cost. Proponents of such reductions,



seeking maximum benefits to coastal waters and additional acid rain reductions, argue that pollution control costs usually decrease as technologies become more widely used.

Ammonia

After NOx, ammonia is the main source of airborne nitrogen reaching the Bay. Ammonia is of particular concern because it is more biologically available than nitrate; that is, algae in the water will use ammonia more quickly than they would the nitrate that ultimately enters the Bay as a result of NOx emissions.

Large "pulses" of ammonia that arrive with rainstorms have the potential of altering the aquatic food web by stimulating the growth of algae species that are able to quickly assimilate large amounts of ammonia which, historically, would not have been available in those areas.

Knowledge of ammonia sources and transport is more sketchy than for NOx, but it is estimated that ammonia could contribute about a quarter of all the airborne nitrogen entering the Chesapeake. Ammonia has many sources, both natural and anthropogenic. The largest single source in the United States is agriculture, which is estimated to account for about 90 percent of ammonia emissions. On farms, ammonia volatilizes into the air from animal wastes and fertilizers.

Expanded livestock operations have raised concerns that ammonia emissions could be increasing both nationwide and in the watershed. Research in North Carolina, for example, has shown that ammonia accounted for 20 percent to 30 percent of atmospheric nitrogen that landed directly on estuarine waters in the late 1970s, but now accounts for 40 percent to 50 percent.

If NOx emissions continue to decrease, ammonia could become an increasingly important source of nitrogen deposition to the Bay and its watershed. This could prove to be particularly significant as agricultural ammonia emissions are not regulated under the Clean Air Act.

Conclusion

After two decades of gradual increase, nationwide NOx emissions decreased in both 1995 and 1996, largely as the result of new acid rain control requirements for major power plants. Aggressive air pollution programs that were announced in 1997 seem likely to result in continued NOx reductions after they begin taking effect, mainly after the turn of the century.

Those reductions will benefit the Bay, but the extent of that benefit remains uncertain. For example, NOx reductions aimed at reducing ozone levels would only need to take place during the summer months. Yet emissions affect the Bay year-round. Meeting the ozone standard during the summer will likely result in a "cap" on NOx emissions during those months, but emissions could grow during the rest of the year, depending on what technologies and strategies are used to achieve the reductions.

Emissions from cars and trucks may be more problematic. From 1970 through 1995, pollution control devices managed to keep NOx emissions constant despite a doubling in the amount of vehicle miles traveled. It is unclear whether new regulations will do much better, especially as vehicle travel is expected to increase as the population grows and development spreads ever farther into the countryside. Also, emission control devices on cars deteriorate over time, particularly if they are not properly maintained. That concern has resulted in the creation of inspection programs in some areas which

Great Waters Program

When the federal Clean Air and Clean Water acts were written in the early 1970s, air pollution and water pollution were considered two separate problems. Research over the years, though, has indicated that what is emitted into the air can fall to the ground and contribute to water pollution problems.

Recognizing this, the 1990 Clean Air Act Amendments established the "Great Waters Program" which required the Environmental Protection Agency, in cooperation with the National Oceanic and Atmospheric Administration, to study the impacts of air pollution on the Great Lakes, Lake Champlain, the Chesapeake Bay and coastal waters.

The law requires that a report on the study be submitted to Congress every two years. The reports must discuss the extent to which atmospheric deposition affects the waters, the effectiveness of existing controls in dealing with those problems, and whether additional regulatory action is needed to reduce atmospheric deposition.

In the most recent Great Waters report, released in the summer of 1997, the EPA determined that no additional air pollution controls were needed at that time to protect water bodies from air pollution, but it called for continued study of the issue.

The EPA's decision has been controversial, though. Some environmental groups have indicated they may file suit against the agency unless it more aggressively deals with impacts of air pollution on water quality.

"Deposition of Air Pollutants to the Great Waters: Second Report to Congress," Environmental Protection Agency, June 1997.

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"Atmospheric Nutrient Input to Coastal Areas: Reducing the Uncertainties," National Oceanic and Atmospheric Administration, Coastal Ocean Program, June 1996.

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"Detroit and Toronto meet the Bay," Bay Journal, March 1995.

"Clean air actions worth millions of dollars to the Bay," Bay Journal, September 1997.

"Using the Regional Acid Deposition Model to Determine the Nitrogen Deposition Airshed of the Chesapeake Bay Watershed," chapter in *Atmospheric Deposition to the Great Lakes and Coastal Waters,* 1997.

"New Air Rules Would Help Bay." Bay Journal, January-February 1997.

Production of this white paper was funded by the Chesapeake Bay Program's Air Subcommittee as a public education service. For information about air pollution and the Chesapeake Bay, contact: 1-800-YOUR-BAY.

The Alliance for the Chesapeake Bay is a nonpartisan, nonprofit group of citizens, scientists, corporations, trade groups, environmental groups and others from throughout the Chesapeake Bay watershed: from Owego, NY through Lancaster, PA to Williamsburg VA, and from Harpers Ferry WV beyond the District of Columbia, to the Eastern Shore of Maryland.

The Alliance does not lobby. It is committed to hands-on restoration, public policy research and education and information services. It puts the collective talents and resources of its diverse membership to work directly on watershed.

For information about the Alliance, call the Chesapeake Regional information Service, 1-800-662-CRIS

ALLIANCE for the CHESAPEAKE BAY